Michigan Department of Environmental Quality
Water Bureau
August 2005

Total Maximum Daily Load for *Escherichia coli* for The Bass River Ottawa County

INTRODUCTION

Section 303(d) of the federal Clean Water Act and the United States Environmental Protection Agency's (USEPA's) Water Quality Planning and Management Regulations (Title 40 of the Code of Federal Regulations (CFR), Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for water bodies that are not meeting water quality standards (WQS). The TMDL process establishes the allowable loadings of pollutants for a water body based on the relationship between pollution sources and in-stream water quality conditions. TMDLs provide states a basis for determining the pollutant reductions necessary from both point and nonpoint sources to restore and maintain the quality of their water resources. The purpose of this TMDL is to identify the allowable levels of *Escherichia coli* (*E. coli*) that will result in the attainment of the applicable WQS in the Bass River, a tributary of the Grand River, located in Ottawa County, Michigan.

PROBLEM STATEMENT

This water body was identified in the Section 303(d) list in 2004 (Wolf and Wuycheck, 2004). This TMDL listing addresses approximately 33 miles of stream in Ottawa County. The TMDL reach is on the 2004 Section 303(d) list as:

BASS RIVER WBID#: 082801H
County: OTTAWA Size: 33 M
Location: Grand River confluence u/s to 92nd Street crossing of Bass and Little Bass rivers.
HUC: 4050006 RF3RchID: 4050006 4
Problem: Pathogens (Rule 100); Fish and macroinvertebrate communities rated poor.
TMDL YEAR(s): 2005

The Bass River (Figure 1) was placed on the Section 303(d) list due to impairment of recreational uses as indicated by the presence of elevated levels of *E. coli*. Monitoring data collected by the Michigan Department of Environmental Quality (MDEQ) in 2004, documented exceedances of the WQS for *E. coli* at all sampling locations during the total body contact recreational season of May 1 through October 31 (Tables 1-3).

NUMERIC TARGET

The impaired designated use addressed by this TMDL is total body contact recreation. Rule 100 of the Part 4 rules, WQS, promulgated under Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, requires that this water body be protected for total body contact recreation from May 1 through October 31. The target levels for this designated use are the ambient *E. coli* standards established in Rule 62 of the WQS as follows:

R 323.1062 Microorganisms.
Rule 62. (1) All waters of the state protected for total body contact recreation shall not contain more than 130 *E. coli* per 100 milliliters (ml), as a 30-day geometric mean. Compliance shall be based on the geometric mean of all individual samples taken during five or more sampling events representatively spread over a 30-day period. Each sampling event shall consist of three or more samples taken at representative locations within a defined sampling area. At no time shall the waters of the state protected for total body contact recreation contain more than a maximum of 300 *E. coli* per 100 ml. Compliance shall be based on the geometric mean of three or more samples taken during the same sampling event at representative locations within a defined sampling area.

For this TMDL, the WQS of 130 *E. coli* per 100 ml as a 30-day geometric mean and 300 *E. coli* per 100 ml as a daily maximum are the target levels for the TMDL reach from May 1 to October 31. As previously stated, the 2004 monitoring data indicated exceedances of WQS at all locations sampled. The highest concentrations are located in the upstream tributaries.

DATA DISCUSSION

The Bass River and selected tributaries were sampled at a total of nine stations (Figure 1). *E. coli* concentrations in the two stations sampled on the Bass River generally decreased from the beginning to nearly the end of the sampling season (Figure 2). Thirty-day geometric mean *E. coli* concentrations in the Bass River ranged from 32 *E. coli* per 100 ml in September at Buchanan Road (BR-08) to 1,002 *E. coli* per 100 ml in June at Buchanan Road (BR-08). Daily geometric mean concentrations ranged from 2 *E. coli* per 100 ml in September at Buchanan Road (BR-08) to 11,680 *E. coli* per 100 ml in May at the same location (Table 1). Both locations on the Bass River experienced the season's highest levels in *E. coli* concentrations (e.g., greater than 6,000 *E. coli* per 100 ml) in response to a rain event on May 19, 2004. It should be noted that a similar rain event on June 9, 2004, did not produce the large concentrations noted in the May event.

Bass Creek, a large tributary of the Bass River, was sampled at four locations (Figure 1). Concentrations appear to decrease in a downstream direction with particularly high concentrations at the two upstream stations (BR-02 and BR-03) (Figure 3, Table 2). Thirty-day geometric mean *E. coli* concentrations ranged from 14 *E. coli* per 100 ml in August at 96th Avenue (BR-04) to 12,352 *E. coli* per 100 ml in July at 88th Avenue (BR-03). Thirty-day geometric mean concentrations at 88th Avenue (BR-03) were greater than 2,000 *E. coli* per 100 ml the entire sampling season, with nine occasions greater than 5,000 *E. coli* per 100 ml. Daily geometric mean concentrations ranged from 2 *E. coli* per 100 ml in August at 96th Avenue (BR-04) to 40,121 *E. coli* per 100 ml in June at 88th Avenue (BR-03).

Three small tributaries were also sampled as part of this TMDL. The highest concentrations were found in the unnamed tributary at 72nd Avenue (BR-01), while the station on Bear Creek at 104th Avenue (BR-07) indicated only slight exceedances of the WQS (Figure 4). Thirty-day geometric mean *E. coli* concentrations ranged from 84 *E. coli* per 100 ml in Bear Creek in July at 104th Avenue (BR-07) to 3,072 *E. coli* per 100 ml in the unnamed tributary in July at 72nd Avenue (BR-01). Daily geometric mean concentrations ranged from 43 *E. coli* per 100 ml in Bear Creek in July at 104th Avenue (BR-07) to 11,598 *E. coli* per 100 ml in the unnamed tributary in July at 72nd Avenue (BR-01) (Table 3). Thirty-day geometric mean concentrations in the unnamed tributary were greater than 2,000 *E. coli* per 100 ml until the last two sampling

events. Daily geometric mean concentrations were greater than 1,000 *E. coli* per 100 ml for the entire sampling season with the exception of one event in September, and four events were greater than 4,000 *E. coli* per 100 ml.

SOURCE ASSESSMENT

The official listed reach for the Bass River is the confluence with the Grand River upstream to the 92nd Avenue (identified as 92nd Street in the listing) crossing of Bass and Little Bass Creek (identified as Little Bass River in the listing). Based on the 2004 sampling data, the modified TMDL listing for pathogens is expanded to include the Bass River, including Bear Creek, Little Bass Creek, and Bass Creek. The 2006 Section 303(d) list will be modified to reflect these changes. The municipalities in the TMDL reach for the Bass River include Robinson Township, Allendale Township, BlendonTownship, Georgetown Township, and Grand Haven Township (Figure 1). Table 4 shows the distribution of land for each municipality.

The primary pathogen sources for this water body appear to be from agricultural land uses. Agriculture accounts for approximately 52 percent of the land use in the Bass River watershed (Cadmus Group, 2005). Secondary sources such as inputs from wild/domestic waterfowl and poorly operating septic systems are also possible sources of *E. coli* to the Bass River.

Field observations indicate intense agriculture in tributaries of the Bass River. Unrestricted livestock access to Bass Creek and Little Bass Creek were noted in a biological survey of the watershed in 1999 (Rockafellow, 2003). Livestock in close proximity to Bass Creek were observed in 2003, by the Ottawa County Health Department, and data indicate the highest exceedances were in the vicinity of Station BR-03 and downstream of Station BR-02 (VanEerden, 2003). Land use in this area continues to include large pastures and agriculture as observed by the MDEQ in 2004. Ducks, geese, and livestock were found in the vicinity of many of the sampling locations in Bass Creek, Little Bass Creek, and the unnamed tributary. The observations made over the past several years with regards to potential sources of *E. coli* appear to be consistent with the 2004 data collected by the MDEQ. Bass Creek at 88th Avenue (BR-03) had nine occasions when the 30-day geometric mean concentrations were greater than 5,000 *E. coli* per 100 ml (Table 2). This location is downstream of the unnamed tributary at 72nd Avenue (BR-01) where *E. coli* concentrations exceeded 2,000 *E. coli* per 100 ml almost the entire sampling season (Table 3).

It should be noted that many of the largest exceedances in Bass Creek at 88th Avenue were observed during dry or nearly dry weather events (i.e., 0.4 inches or less of precipitation recorded within 24 hours of sampling). This indicates a dry weather source of *E. coli*, such as animals in, or within close proximity to, the stream. Due to the substantial *E. coli* concentrations at this location, a sample was collected for Deoxyribonucleic acid (DNA) ribotyping analysis. This is a relatively new technology that extracts DNA from *E. coli* isolates and compares the DNA to a library of known source isolates. This analysis is used to distinguish human from non-human sources of *E. coli* and is valuable when targeting areas for improvements that will benefit water quality. The sample was collected on July 15, 2004. The results indicate all isolates were of nonhuman origin (Table 5).

A large portion of Ottawa County utilizes on-site septic systems for waste treatment. The Ottawa County Health Department estimates as many as ten percent of systems are found to be failing when inspections are conducted (London, 2005). These failures could be contributing *E. coli* to the Bass River TMDL watershed.

Currently, there are 15 National Pollutant Discharge Elimination System (NPDES) permitted discharges to the Bass River or its tributaries in the TMDL reach (Table 6, Figure 5); one industrial storm water permit, five municipal separate storm sewer system permits (MS4s), and nine notice of coverage (NOC) permits. The industrial storm water discharge is not considered to contain treated or untreated human sewage or animal waste; therefore, is not considered a significant source of *E. coli* to the Bass River TMDL watershed. The five MS4 permits may be sources of *E. coli*. The NOC permits involve earth work in the TMDL watershed and likely are not significant sources of *E. coli* to the watershed.

LINKAGE ANALYSIS

Determining the link between the *E. coli* concentrations in the Bass River and the potential sources is necessary to develop the TMDL. This link provides the basis for estimating the total assimilative capacity of the river and any needed load reductions. For this TMDL, the highest concentrations of pathogens were measured during dry weather. Potential sources include farm animal access to the stream(s), wild/domestic waterfowl, and failing or poorly functioning septic systems. Secondary sources include agricultural runoff.

To further investigate the potential sources mentioned above, a load duration curve analysis was conducted for each sampling station using guidance provided by Cleland (2002) (Appendix A). A load duration curve is a relatively new method utilized in TMDL development and considers how flow conditions relate to pollutant sources (point and nonpoint sources). Dots above the curve on the far left side of the figure indicate *E. coli* WQS exceedances during wet weather conditions, while dots above the curve on the middle to right side of the figure indicate WQS exceedances during lower flow conditions, such as those experienced during dry weather. Dots below the curve indicate WQS attainment for the respective flow condition.

Flows for ungaged watersheds were estimated using a gaged stream from a nearby watershed of similar size and land use characteristics. The United States Geological Survey gage, used to estimate the flows discussed here, is located on Bear Creek near Muskegon (Gage Number 04122100).

The data indicate that exceedances of the WQS are observed at certain stations during all flow conditions, specifically Bass Creek at 72nd Avenue (BR-02), Bass Creek at 88th Avenue (BR-03), the unnamed tributary at 72nd Avenue (BR-01), and Little Bass Creek at 96th Avenue (BR-05). These data lend support to the existence of dry weather sources of *E. coli* such as direct animal access to the creek and potential illicit discharges.

The guiding water quality management principle used to develop the TMDL was that compliance with the numeric pathogen target in the Bass River depends on the control of *E. coli* during both wet and dry weather conditions. If the *E. coli* inputs can be controlled to meet the numeric standards, then total body contact recreation in the Bass River will be restored and protected.

TMDL DEVELOPMENT

The TMDL represents the maximum loading that can be assimilated by the water body while still achieving WQS. As indicated in the Numeric Target section, the targets for this pathogen TMDL are the 30-day geometric mean WQS of 130 *E. coli* per 100 ml and daily geometric mean of 300 *E. coli* per 100 ml. Concurrent with the selection of a numeric concentration endpoint, TMDL development also defines the environmental conditions that will be used when defining

allowable levels. Many TMDLs are designed around the concept of a "critical condition." The "critical condition" is defined as the set of environmental conditions that, if controls are designed to protect, will ensure attainment of objectives for all other conditions. For example, the critical conditions for the control of point sources in Michigan are given in R 323.1082 and R 323.1090. In general, the lowest monthly 95 percent exceedance flow for streams is used as a design condition for point source discharges. However, for pathogens in point source discharges of treated or untreated human sewage, levels are restricted to a monthly average limit of 200 Fecal coliform per 100 ml regardless of stream flow. Therefore, the design stream flow is not a critical condition for determining the allowable loading of pathogen for wastewater treatment plants. In addition, sources of pathogens to the Bass River arise from a mixture of wet and dry weather-driven nonpoint sources. For these sources, there are a number of different allowable loads that will ensure compliance, as long as they are distributed properly throughout the watershed.

For most pollutants, TMDLs are expressed on a mass loading basis (e.g., pounds per day). For *E. coli*, however, mass is not an appropriate measure, and the USEPA allows pathogen TMDLs to be expressed in terms of organism counts (or resulting concentration) (USEPA, 2001). Therefore, this pathogen TMDL is concentration based consistent with R 323.1062, and the TMDL is equal to the target concentration of 130 *E. coli* per 100 ml as a 30-day geometric mean and daily geometric mean of 300 *E. coli* per 100 ml in all portions of the TMDL reach for each month of the recreational season (May through October). Expressing the TMDL as a concentration equal to the WQS ensures that the WQS will be met under all flow and loading conditions; therefore, a critical condition is not applicable for this TMDL.

ALLOCATIONS

TMDLs are comprised of the sum of individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly within the WLA or LA, or explicitly, that accounts for uncertainty in the relationship between pollutant loads and the quality of the receiving water body. Conceptually, this definition is denoted by the equation:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

The term TMDL represents the maximum loading that can be assimilated by the receiving water while still achieving WQS. This pathogen TMDL will not be expressed on a mass loading basis and is concentration based consistent with USEPA regulations in 40 CFR, Section 130.2(i).

WLAs

There are a total of 15 permitted point source discharges to the listed reach of the Bass River; one industrial storm water permit, five MS4 permits, and nine NOC permits for earthwork. The industrial storm water permitted discharge is not considered a significant source of *E. coli* to the Bass River due to Best Management Practices required in the permit. This permit does not authorize the discharge of non-storm water and it requires a certified storm water operator for the facility. The MS4 permits may contain *E. coli* due to materials washing into the storm drains during wet weather events; therefore, the WLA is equal to the WQS of 130 *E. coli* per 100 ml. The NOC permits involve earth work in the watershed and, due to the nature of the permits, are not considered significant sources of *E. coli* to the Bass River.

LAs

Because this TMDL is concentration based, the LA is equal to 130 *E. coli* per 100 ml. This is based on the assumption that all land, regardless of use, will be required to meet the WQS. Therefore, the relative responsibility for achieving the necessary reductions of bacteria and maintaining acceptable conditions will be determined by the amount of land under the jurisdiction of the local unit of government in the watershed. This TMDL reach is located in the townships of Allendale, Robinson, Blendon, Georgetown, and Grand Haven.

MOS

This section addresses the incorporation of an MOS in the TMDL analysis. The MOS accounts for any uncertainty or lack of knowledge concerning the relationship between pollutant loading and water quality, including the pollutant decay rate if applicable. The MOS can be either implicit (i.e., incorporated into the WLA or LA through conservative assumptions) or explicit (i.e., expressed in the TMDL as a portion of the loadings). This TMDL uses an implicit MOS because no rate of decay was used. Pathogen organisms have a limited capability to survive outside of their hosts and a rate of decay could be developed. However, rates of decay are highly variable depending on environmental conditions and applying a rate of decay could result in an allocation that would be greater than the WQS if the decay rate was over-predicted. Thus, no rate of decay is applied in order to assure attainment of WQS. The MDEQ has determined that the use of the WQS of 130 *E. coli* per 100 ml for the WLA and LA is a more conservative approach than developing an explicit MOS and accounts for the uncertainty in the relationship between pollutant loading and water quality and the assumption to not use a rate of decay. Applying the WQS to be met under all flow conditions also adds to the assurance that an explicit MOS is unnecessary.

SEASONALITY

Seasonality in the TMDL is addressed by expressing the TMDL in terms of a total body contact recreation season that is defined as May 1 through October 31, by R 323.1100 of the WQS. There is no total body contact during the remainder of the year primarily due to cold weather. In addition, because this is a concentration-based TMDL, WQS will be met regardless of flow conditions in the applicable season.

MONITORING

In 2004, pathogens were monitored weekly at a total of nine stations from May through September. Future monitoring will take place as part of the five-year rotating basin following implementation of appropriate control measures to eliminate sources of *E. coli* to the watershed. When these results indicate that the water body may be meeting WQS, sampling will be conducted at the appropriate frequency (as defined in the numeric target section) to determine if the 30-day geometric mean value of 130 *E. coli* per 100 ml and 300 *E. coli* per 100 ml as a daily maximum are being met.

REASONABLE ASSURANCE ACTIVITIES

Georgetown, Allendale, and Blendon Townships are under MS4 permits. These townships are participating with other communities with MS4s in a watershed-based storm water program for the lower Grand River. These partnerships will aid in implementing the required activities that

will likely reduce *E. coli* inputs to surface waters through public education, a storm water management plan, and illicit connection identification and elimination requirements.

Allendale and Georgetown Townships have conducted reconnaissance of the waters within all urbanized areas of the townships where there was a potential for storm water outfalls from a municipal separate storm water system. Each outfall was mapped and cataloged with documentation on any unusual odors or colors in the discharge. In coordination with the Ottawa County Health Department, several sites suspected of illicit discharges were recommended for follow-up action. Public education activities include a newsletter and workshop aimed at riparian owners, watershed resource users, public officials, home gardeners, developers, and landscapers (Allendale Township, 2004; Georgetown Township, 2004).

Blendon Township is in the process of developing a storm water management plan. They expect full implementation of their plan by December 1, 2008. The plan contains six minimum measures, and includes a public education program, a public participation component, an illicit discharge elimination program, a post-construction storm water management program for new and redeveloped sites, development of construction storm water runoff controls, and pollution prevention/good housekeeping for municipal operations. These activities will improve water quality within the TMDL watershed by focusing on educating the public on how their activities affect water quality, and will also require improved management of activities under municipal control (i.e., controlling storm water runoff from new development and better management of municipal facilities, such as parks and equipment garages). The illicit discharge program will be done in cooperation with the Ottawa County Drain Commissioner who will be conducting dry weather screening of all outfalls that have flow in the township. In addition, Ottawa County has implemented a time-of-sale inspection of septic systems. This requires each system to be functioning properly before the sales transaction can be completed.

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REFERENCES

Allendale Township, 2004. Allendale Township, Michigan, NPDES Phase 2 Watershed Permit Annual Report – September 28, 2004. Certificate of Coverage MIG610120.

Cadmus Group, 2005. Total suspended solids, stable flow, and wet weather event monitoring in The Bass River Watershed. Prepared for the Michigan Department of Environmental Quality by the Cadmus Group, report number MI/DEQ/WB-05/018.

Cleland, B. 2002. TMDL Development from the "Bottom Up" – Part II. Using Duration Curves to Connect the Pieces. America's Clean Water Foundation.

Georgetown Township, 2004. Georgetown Township, Michigan. NPDES Phase 2 Watershed Permit Annual Report – 2004. Certificate of Coverage MIG610209.

London, A. 2005. Personal Communication. Ottawa County Health Department.

Rockafellow, D. 2003. A biological survey of the Bass River Watershed Ottawa County, Michigan, July 1999. Report number MI/DEQ/WD-03/056.

USEPA. 2001. Protocol for Developing Pathogen TMDLs. United States Environmental Protection Agency, 841-R-00-002.

VanEerden, L. 2003. Ottawa County Health Department. Bass River Sampling.

Wolf, S. and J. Wuycheck. 2004. Water Quality and Pollution Control in Michigan: 2004 Sections 303(d) and 305(b) Integrated Report. Michigan Department of Environmental Quality, Report Number MI/DEQ/WD-04/029.

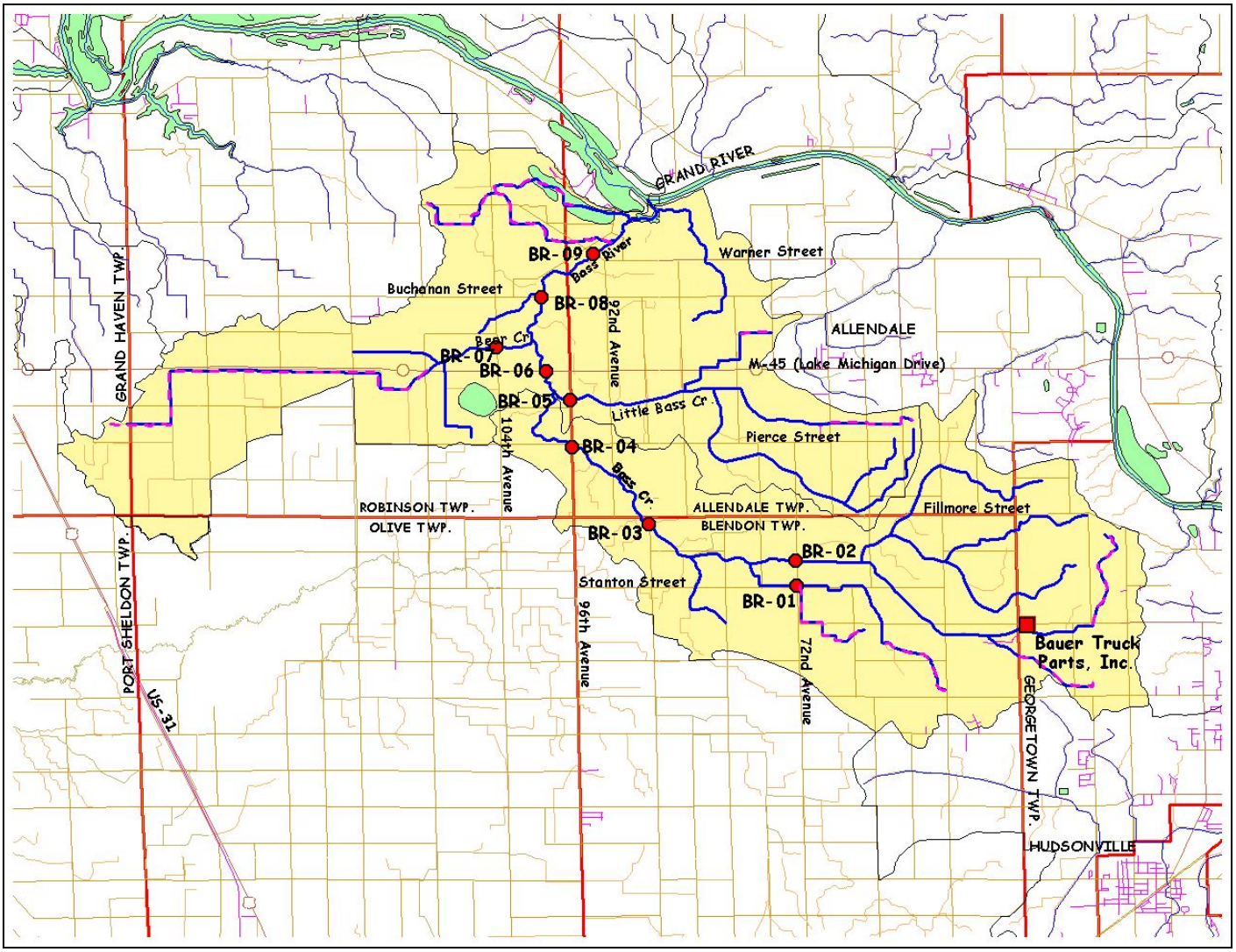

Figure 1. The Bass River *E. coli* sampling locations, including tributaries, Ottawa County, Michigan, 2004. Shaded areas represent the TMDL watershed.

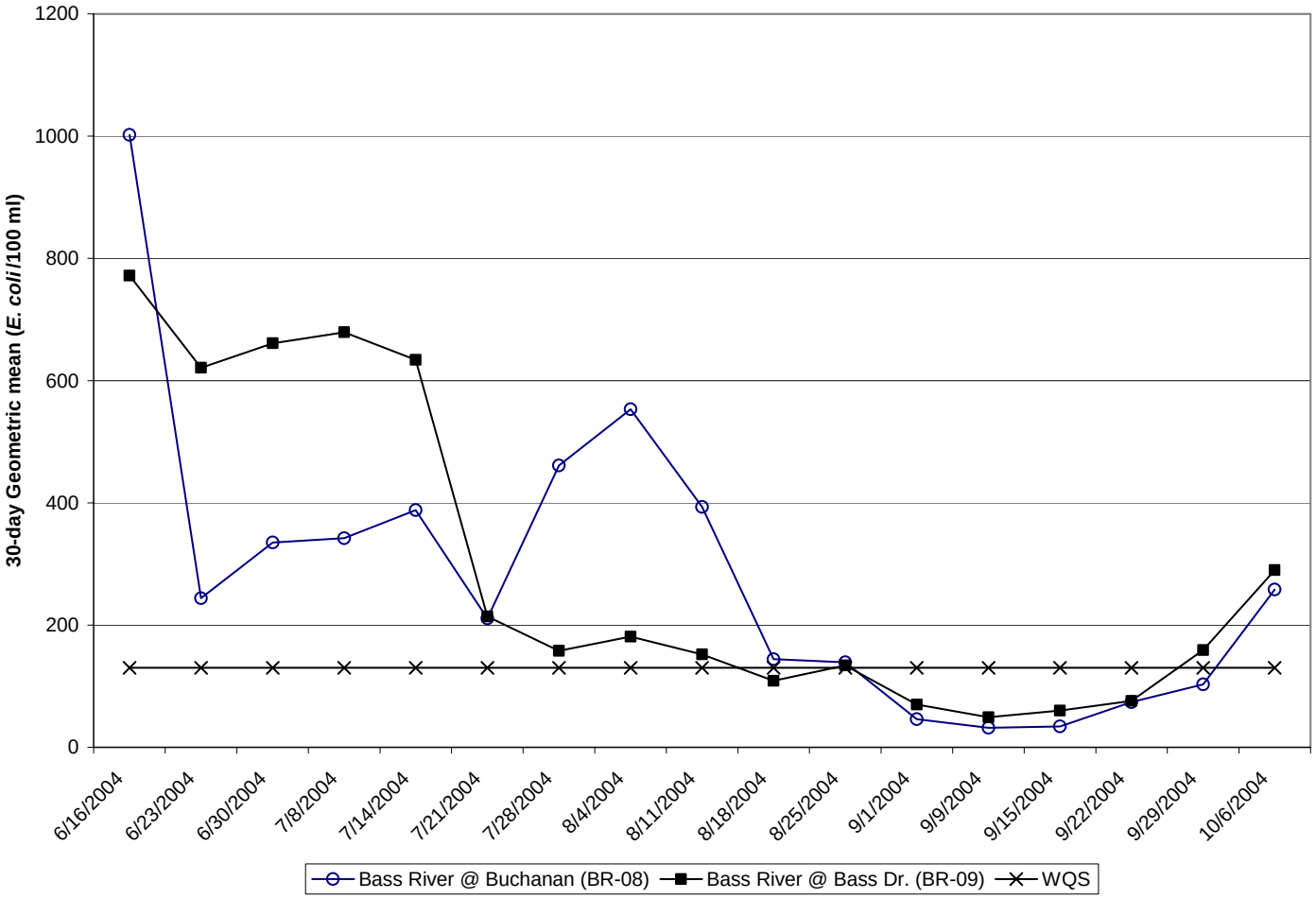

Figure 2. Thirty-day Geometric mean for *E. coli* in the Bass River, Ottawa County, Michigan, 2004.

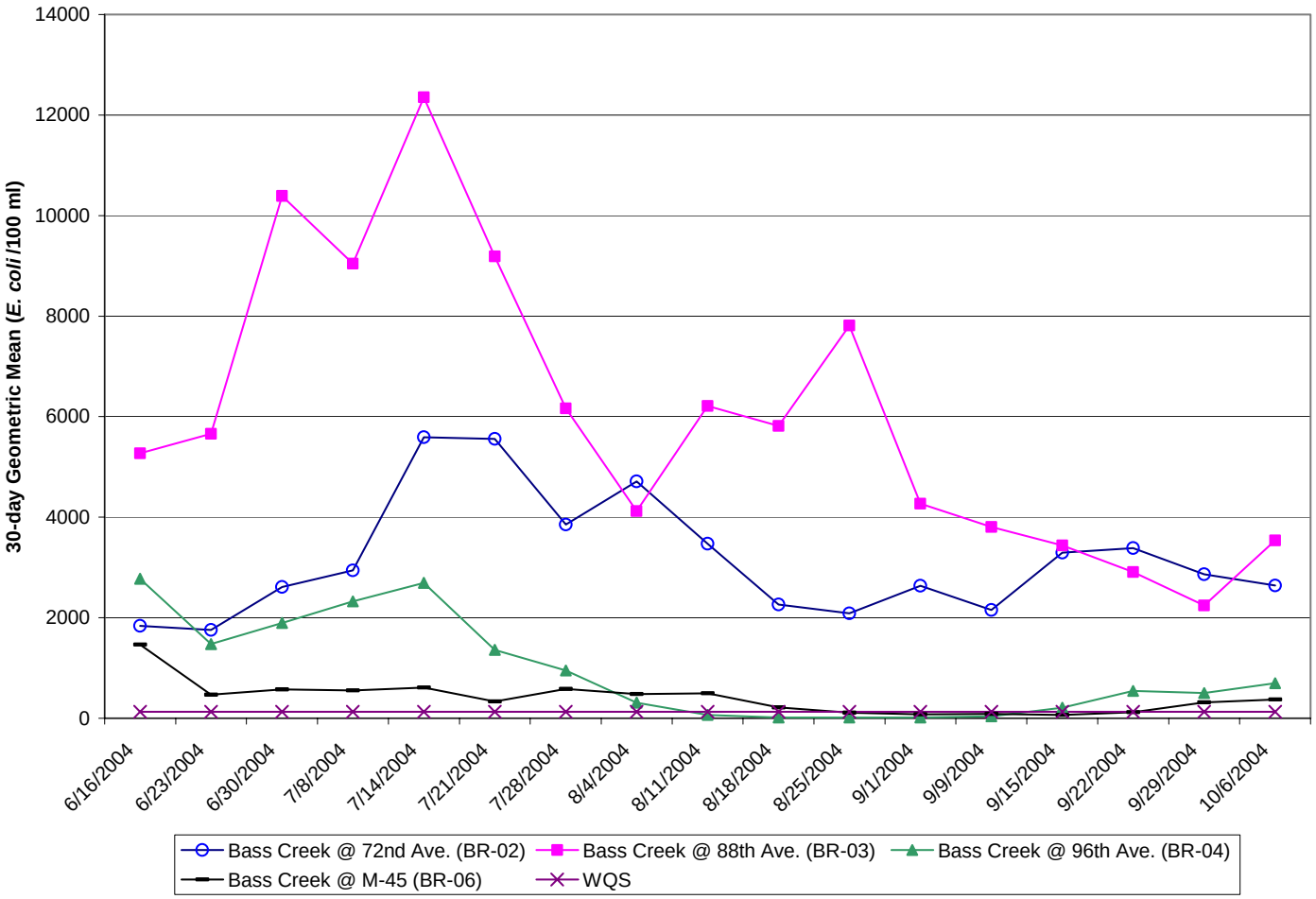

Figure 3. Thirty-day Geometric mean for *E. coli* in Bass Creek, Ottawa County, Michigan, 2004.

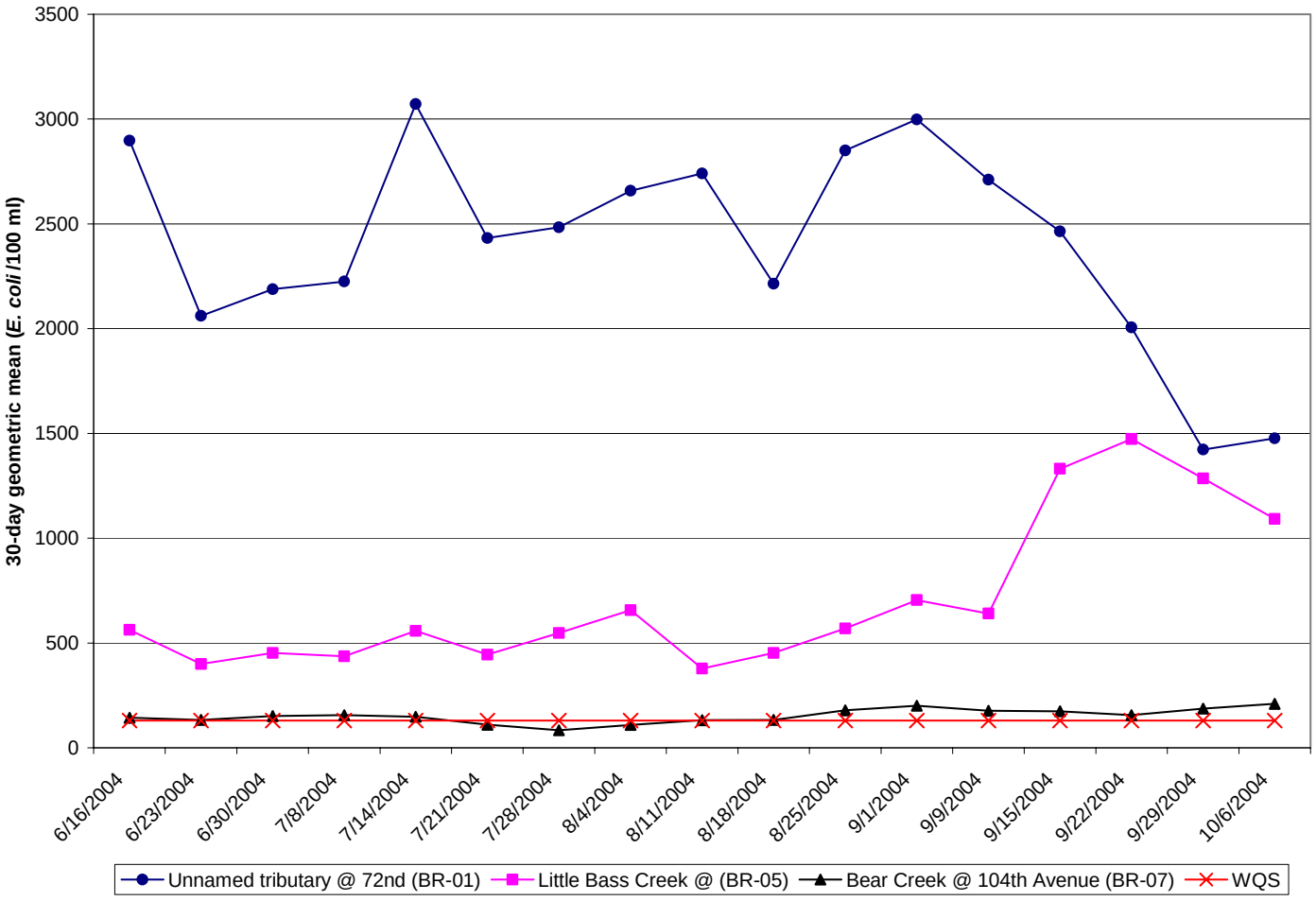

Figure 4. Thirty-day Geometric mean for *E. coli* in tributaries of the Bass River, Ottawa County, Michigan, 2004.

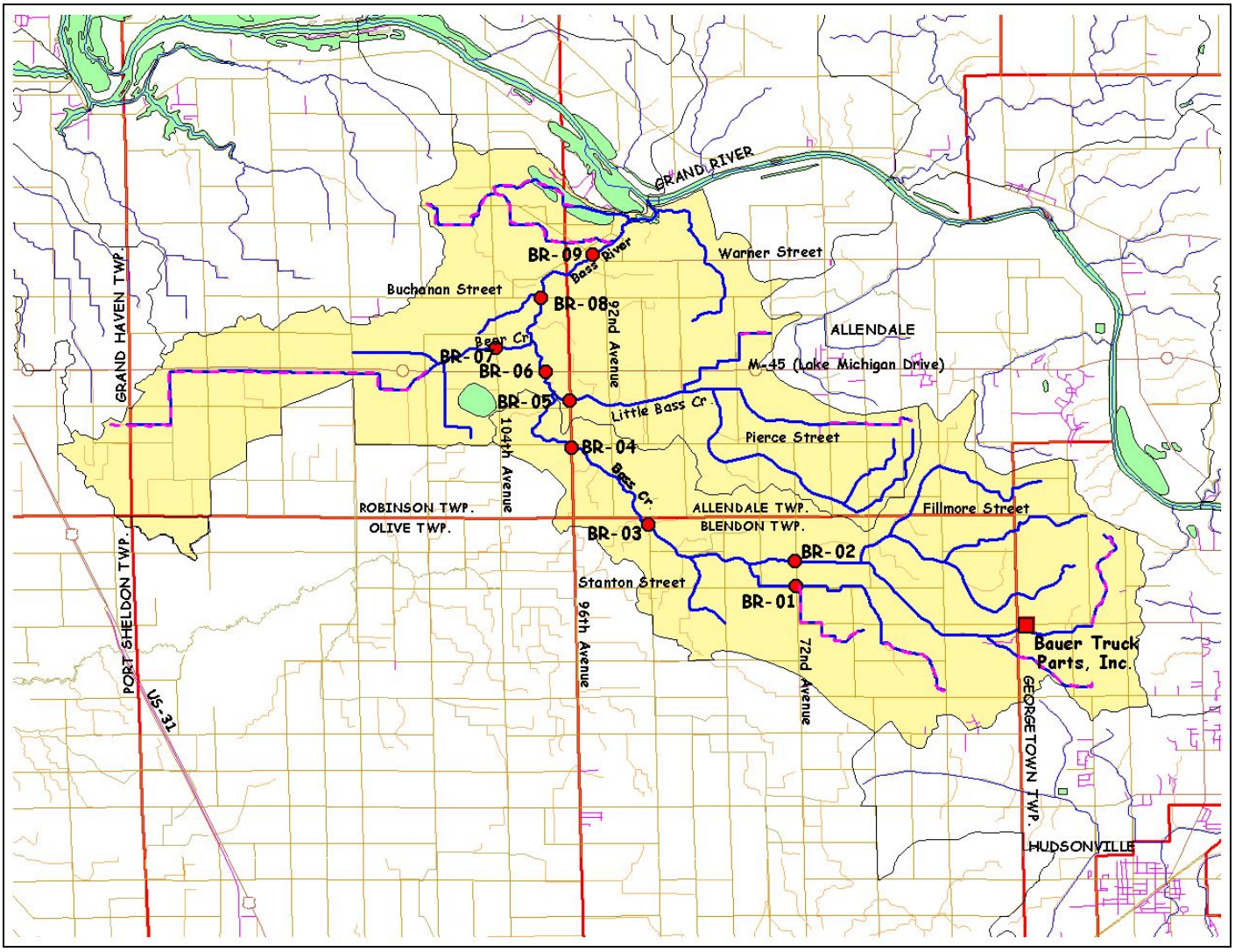

Figure 5. NPDES industrial stormwater discharge to the Bass River, Ottawa County, Michigan, 2004.

***Note: NOC and MS4 permits are not included.**

Table 1. MDEQ 2004 *E. coli* monitoring data for the Bass River (*E. coli* per 100 ml). Shaded areas indicate exceedances of the WQS.

	Bass River @ Buchanan Road (BR-08)			Bass River @ Bass Drive (BR-09)			
DATE	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**Weather Data/Precip.**
5/19/2004	8300	11680	---	5800	6381	---	68°, 2.0"
	12000			7000			
	16000			6400			
5/26/2004	67	144	---	670	143	---	69°, 1.5"
	670			66			
	67			66			
6/3/2004	900	854	---	570	572	---	70°, 0.0"
	900			670			
	770			490			
6/9/2004	520	533	---	700	768	---	73°, 2.2"
	530			1200			
	550			540			
6/16/2004	2600	1318	1002	670	685	772	73°, 0.0"
	800			480			
	1100			1000			
6/23/2004	10	10	244	1700	2154	621	76°, 0.3"
	10			2800			
	10			2100			
6/30/2004	580	700	335	10	195	661	78°, 0.0"
	800			800			
	740			930			
7/8/2004	900	948	342	610	651	679	80°, 0.1"
	1100			870			
	860			520			
7/14/2004	1100	1005	388	320	547	634	80°, 0.4"
	1200			800			
	770			640			

Table 1 continued (*E. coli* per 100 ml).

	Bass River @ Buchanan Road (BR-08)			Bass River @ Bass Drive (BR-09)			
DATE	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**Weather Data/Precip.**
7/21/2004	490	63	211	3	3	214	80°, 0.0"
	50			3			
	10			3			
7/28/2004	620	496	461	560	476	158	79°, 0.0"
	580			370			
	340			520			
8/4/2004	3300	1749	553	3	381	181	79°, 0.2"
	2700			4600			
	600			4000			
8/11/2004	10	171	393	10	276	152	76°, 0.1"
	630			700			
	790			3000			
8/18/2004	3	7	144	2	103	109	78°, 0.3"
	10			870			
	10			630			
8/25/2004	2	52	139	2	8	134	77°, 0.0"
	77			10			
	920			30			
9/1/2004	2	2	46	2	18	70	76°, 0.0"
	2			2			
	2			1400			
9/9/2004	270	301	32	64	64	49	74°, 0.0"
	290			16			
	350			260			

Table 1 continued (*E. coli* per 100 ml).

	Bass River @ Buchanan Road (BR-08)			Bass River @ Bass Drive (BR-09)			
DATE	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**Weather Data/Precip.**
9/15/2004	3	220	34	800	800	60	69°, 0.0"
	1700			800			
	2100			800			
9/22/2004	240	330	74	420	323	76	65°, 0.0"
	300			170			
	500			470			
9/29/2004	230	268	103	630	343	159	65°, 0.1"
	240			200			
	350			320			
10/6/2004	250	193	258	480	361	290	61°, 0.0"
	260			350			
	110			280			

Table 2. MDEQ 2004 *E. coli* monitoring data for Bass Creek (*E. coli* per 100 ml). Shaded areas indicate exceedances of the WQS.

	Bass Creek @ 72nd Avenue (BR-02)			Bass Creek @ 88th Avenue (BR-03)			Bass Creek @ 96th Avenue (BR-04)			
DATE	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**Weather Data/Precip.**
5/19/2004	2000	3382	---	25000	28189	---	28000	16048	---	68°, 2.0"
	4500			32000			18000			
	4300			28000			8200			
5/26/2004	290	338	---	970	1264	---	1200	708	---	69°, 1.5"
	460			1600			800			
	290			1300			370			
6/3/2004	2700	1986	---	5000	4428	---	1400	1558	---	70°, 0.0"
	1000			5600			1500			
	2900			3100			1800			
6/9/2004	180	1075	---	4700	3786	---	1200	2565	---	73°, 2.2"
	2300			3500			3700			
	3000			3300			3800			
6/16/2004	8000	8542	1836	5700	6814	5271	4400	3628	2776	73°, 0.0"
	8200			7500			3100			
	9500			7400			3500			
6/23/2004	2700	2733	1759	39000	40121	5657	33	683	1476	76°, 0.3"
	2100			36000			2300			
	3600			46000			4200			
6/30/2004	1700	2436	2611	22000	26407	10389	2500	2463	1894	78°, 0.0"
	2500			31000			2300			
	3400			27000			2600			
7/8/2004	3700	3593	2940	1900	2215	9045	3900	4318	2323	80°, 0.1"
	3300			2200			4300			
	3800			2600			4800			
7/14/2004	30000	26749	5591	17000	17981	12352	2700	5350	2691	80°, 0.4"
	22000			18000			6300			
	29000			19000			9000			

Table 2 continued (*E. coli* per 100 ml).

	Bass Creek @ 72nd Avenue (BR-02)			Bass Creek @ 88th Avenue (BR-03)			Bass Creek @ 96th Avenue (BR-04)			
DATE	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**Weather Data/Precip.**
7/21/2004	4700	8285	5557	100	1552	9189	33	120	1361	80°, 0.0"
	11000			1700			33			
	11000			22000			1600			
7/28/2004	1700	438	3854	2500	5457	6165	650	112	948	79°, 0.0"
	1500			5000			3			
	33			13000			720			
8/4/2004	3000	6647	4711	33	3527	4122	3	9	309	79°, 0.2"
	8900			38000			3			
	11000			35000			83			
8/11/2004	2700	779	3469	20000	17213	6212	2	2	67	76°, 0.1"
	33			15000			2			
	5300			17000			2			
8/18/2004	2400	3169	2265	10000	12927	5815	2	2	14	78°, 0.3"
	7800			12000			2			
	1700			18000			2			
8/25/2004	2800	5496	2086	100	6787	7811	270	270	16	77°, 0.0"
	7700			59000			270			
	7700			53000			270			
9/1/2004	2200	1412	2636	3	266	4267	3	124	16	76°, 0.0"
	800			2400			800			
	1600			2600			800			
9/9/2004	2100	2420	2154	800	1995	3807	740	765	40	74°, 0.0"
	2700			3200			730			
	2500			3100			830			

Table 2 continued (*E. coli* per 100 ml).

	Bass Creek @ 72nd Avenue (BR-02)			Bass Creek @ 88th Avenue (BR-03)			Bass Creek @ 96th Avenue (BR-04)			
DATE	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**Weather Data/Precip.**
9/15/2004	5800	6530	3295	10000	10307	3436	5000	7969	210	69°, 0.0"
	3200			15000			9200			
	15000			7300			11000			
9/22/2004	6600	3630	3386	4800	5633	2910	1000	236	546	65°, 0.0"
	2500			3800			33			
	2900			9800			400			
9/29/2004	2000	2381	2865	1500	1847	2243	20	178	502	65°, 0.1"
	2500			2100			470			
	2700			2000			600			
10/6/2004	800	942	2642	1900	2586	3536	3300	650	699	61°, 0.0"
	1200			3500			260			
	870			2600			320			

Table 2 continued (*E. coli* per 100 ml).

	Bass Creek @ M-45 (BR-06)			
DATE	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**Weather Data/Precip.**
5/19/2004	21000	13219	---	68°, 2.0"
	10000			
	11000			
5/26/2004	170	265	---	69°, 1.5"
	330			
	330			
6/3/2004	910	966	---	70°, 0.0"
	1100			
	900			
6/9/2004	1200	1200	---	73°, 2.2"
	1200			
	1200			
6/16/2004	2000	1673	1466	73°, 0.0"
	1800			
	1300			
6/23/2004	10	45	470	76°, 0.3"
	10			
	900			
6/30/2004	880	711	573	78°, 0.0"
	470			
	870			
7/8/2004	870	827	556	80°, 0.1"
	700			
	930			
7/14/2004	2100	1963	613	80°, 0.4"
	1800			
	2000			

Table 2 continued (*E. coli* per 100 ml).

	Bass Creek @ M-45 (BR-06)			
DATE	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**Weather Data/Precip.**
7/21/2004	460	82	335	80°, 0.0"
	40			
	30			
7/28/2004	970	699	581	79°, 0.0"
	440			
	800			
8/4/2004	3	275	481	79°, 0.2"
	2900			
	2400			
8/11/2004	530	962	495	76°, 0.1"
	700			
	2400			
8/18/2004	10	32	217	78°, 0.3"
	320			
	10			
8/25/2004	3	3	112	77°, 0.0"
	3			
	3			
9/1/2004	800	109	77	76°, 0.0"
	2			
	800			
9/9/2004	420	501	87	74°, 0.0"
	610			
	490			

Table 2 continued (*E. coli* per 100 ml).

	Bass Creek @ M-45 (BR-06)			
DATE	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**Weather Data/Precip.**
9/15/2004	1900	290	68	69°, 0.0"
	3			
	4300			
9/22/2004	720	490	118	65°, 0.0"
	340			
	480			
9/29/2004	570	416	317	65°, 0.1"
	350			
	360			
10/6/2004	340	245	373	61°, 0.0"
	180			
	240			

Table 3. MDEQ 2004 *E. coli* monitoring data for tributaries of the Bass River (*E. coli* per 100 ml). Shaded areas indicate exceedances of the WQS.

	Unnamed tributary @ 72nd Avenue (BR-01)			Little Bass Creek @ 96th Avenue (BR-05)			Bear Creek @ 104th Avenue (BR-07)			
DATE	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**Weather Data/Precip.**
5/19/2004	7000	7740	---	680	678	---	770	269	---	68°, 2.0"
	7200			610			180			
	9200			750			140			
5/26/2004	1400	1333	---	430	371	---	77	70	---	69°, 1.5"
	1300			330			70			
	1300			360			63			
6/3/2004	2400	2210	---	970	879	---	130	133	---	70°, 0.0"
	1800			700			130			
	2500			1000			140			
6/9/2004	2500	2311	---	10	213	---	170	126	---	73°, 2.2"
	2600			800			97			
	1900			1200			120			
6/16/2004	3300	3873	2897	2700	1195	562	140	189	143	73°, 0.0"
	3200			680			270			
	5500			930			180			
6/23/2004	670	1410	2061	230	124	400	230	191	133	76°, 0.3"
	1900			10			160			
	2200			830			190			
6/30/2004	1400	1796	2188	600	685	453	150	128	151	78°, 0.0"
	1800			800			100			
	2300			670			140			
7/8/2004	2000	2406	2225	570	739	437	220	157	156	80°, 0.1"
	2900			970			160			
	2400			730			110			
7/14/2004	13000	11598	3072	640	723	558	130	96	148	80°, 0.4"
	10000			970			78			
	12000			610			87			

Table 3 continued (*E. coli* per 100 ml).

	Unnamed tributary @ 72nd Avenue (BR-01)			Little Bass Creek @ 96th Avenue (BR-05)			Bear Creek @ 104th Avenue (BR-07)			
DATE	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**Weather Data/Precip.**
7/21/2004	730	1206	2432	890	386	445	190	43	110	80°, 0.0"
	1600			190			2			
	1500			340			210			
7/28/2004	3600	1566	2484	640	350	548	70	50	84	79°, 0.0"
	970			240			38			
	1100			280			46			
8/4/2004	3300	2517	2658	3600	1697	657	450	472	109	79°, 0.2"
	2300			1400			650			
	2100			970			360			
8/11/2004	2500	2804	2740	10	46	378	420	407	132	76°, 0.1"
	2100			10			320			
	4200			1000			500			
8/18/2004	4700	4006	2215	1900	1784	453	140	103	133	78°, 0.3"
	2400			2300			83			
	5700			1300			93			
8/25/2004	3600	4244	2850	1800	1212	569	160	188	179	77°, 0.0"
	5900			900			230			
	3600			1100			180			
9/1/2004	2800	2019	2998	770	1023	705	73	90	201	76°, 0.0"
	1400			870			90			
	2100			1600			110			
9/9/2004	1800	1520	2711	1200	1047	640	230	244	177	74°, 0.0"
	1500			1100			300			
	1300			870			210			

Table 3 continued (*E. coli* per 100 ml).

	Unnamed tributary @ 72nd Avenue (BR-01)			Little Bass Creek @ 96th Avenue (BR-05)			Bear Creek @ 104th Avenue (BR-07)			
DATE	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**SAMPLE RESULTS**	**DAILY G. MEAN**	**30-day G. MEAN**	**Weather Data/Precip.**
9/15/2004	300	1741	2464	2100	1805	1331	250	378	174	69°, 0.0"
	2200			1400			490			
	8000			2000			440			
9/22/2004	1000	1433	2006	8000	2953	1473	270	59	156	65°, 0.0"
	2100			2300			260			
	1400			1400			3			
9/29/2004	830	763	1423	420	616	1286	410	470	187	65°, 0.1"
	670			670			550			
	800			830			460			
10/6/2004	2400	2425	1477	350	453	1092	300	158	210	61°, 0.0"
	2200			500			120			
	2700			530			110			

Table 4. Distribution of land for each municipality in the Bass River TMDL reach.

Municipality	Square Miles	Percent
Allendale Township	16.1	32.4
Robinson Township	15.0	30.2
Blendon Township	12.9	25.9
Georgetown Township	4.9	9.9
Grand Haven Township	0.8	1.6
TOTAL	**49.7**	**100**

Table 5. Discriminant Analysis of Ribotype Profiles of *E. coli* isolates from water sample received from Bass Creek at 88th Avenue (BR-03) on July 15, 2004.

Fecal coliform mpn*/100 ml	*E. coli* isolate number (5 colonies of cultured *E. coli* were analyzed)	Probable Source
>2,400	1	Non-human
	2	Non-human
	3	Non-human
	4	Non-human
	5	Non-human

*mpn = most probable number of fecal coliforms in 100 mL of sample after 20 hrs of cultivation at 44.5 degrees Celcius.

Table 6. Permitted outfalls to the Bass River TMDL watershed. Source: MDEQ, Water Bureau's NPDES Permit Management System.

Facility	Permit Number	Receiving Water	Township	Latitude	Longitude
Bauer Truck Parts, Inc.	MIS210110	Bass River	Georgetown		
CS & Z – Arcadia Woods	MIR104463		Allendale		
Georgetown Township Ice Arena	MIR106759		Georgetown		
GVD – Hidden Shores	MIR105822		Allendale		
GVI – Schepers Farms Sanitary Sewer	MIR107098		Georgetown		
Hidden Acres – Traders Creek	MIR107610		Allendale		
Jay Schippers - Woodbriar	MIR107344		Allendale		

Table 6 continued.

Facility	Permit Number	Receiving Water	Township	Latitude	Longitude
JBS Ltd. LLC - Arcada Woods #2	MIR107906		Allendale		
Quest-Bittersweet Estates #3	MIR105056		Allendale		
Equite Real Estate – Bauer Crossings	MIR108471		Allendale		
Allendale Township MS4	MIG610120		Allendale		
Blendon Township MS4	MIS040007		Blendon		
Georgetown Township MS4	MIG610209		Georgetown		
Grand Haven Township MS4	MIG610207		Grand Haven		
Robinson Township MS4	MIS040059		Robinson		

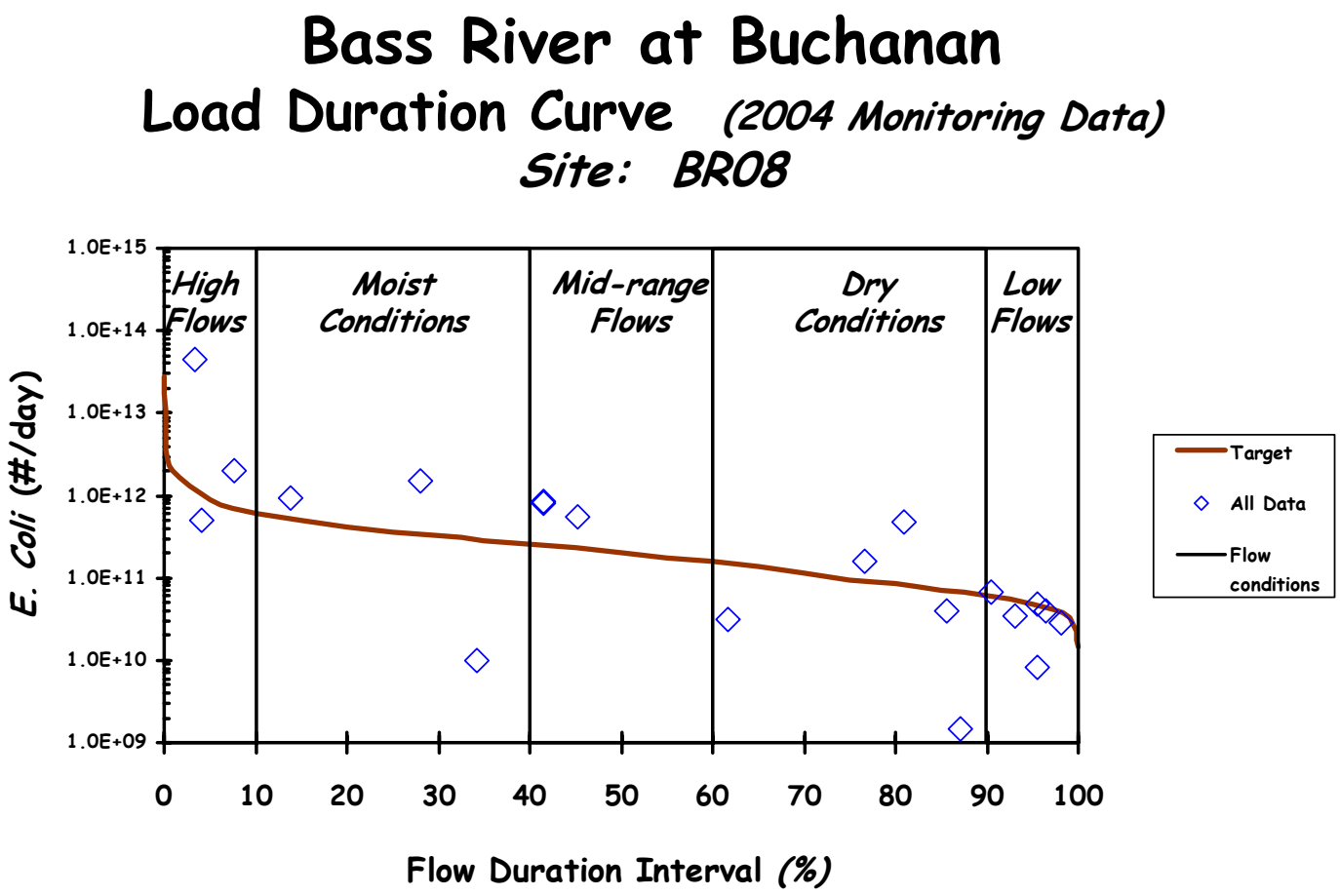

Figure A-1. Bass River at Buchanan Road. Load duration curve based on daily geometric mean. Site: BR-08

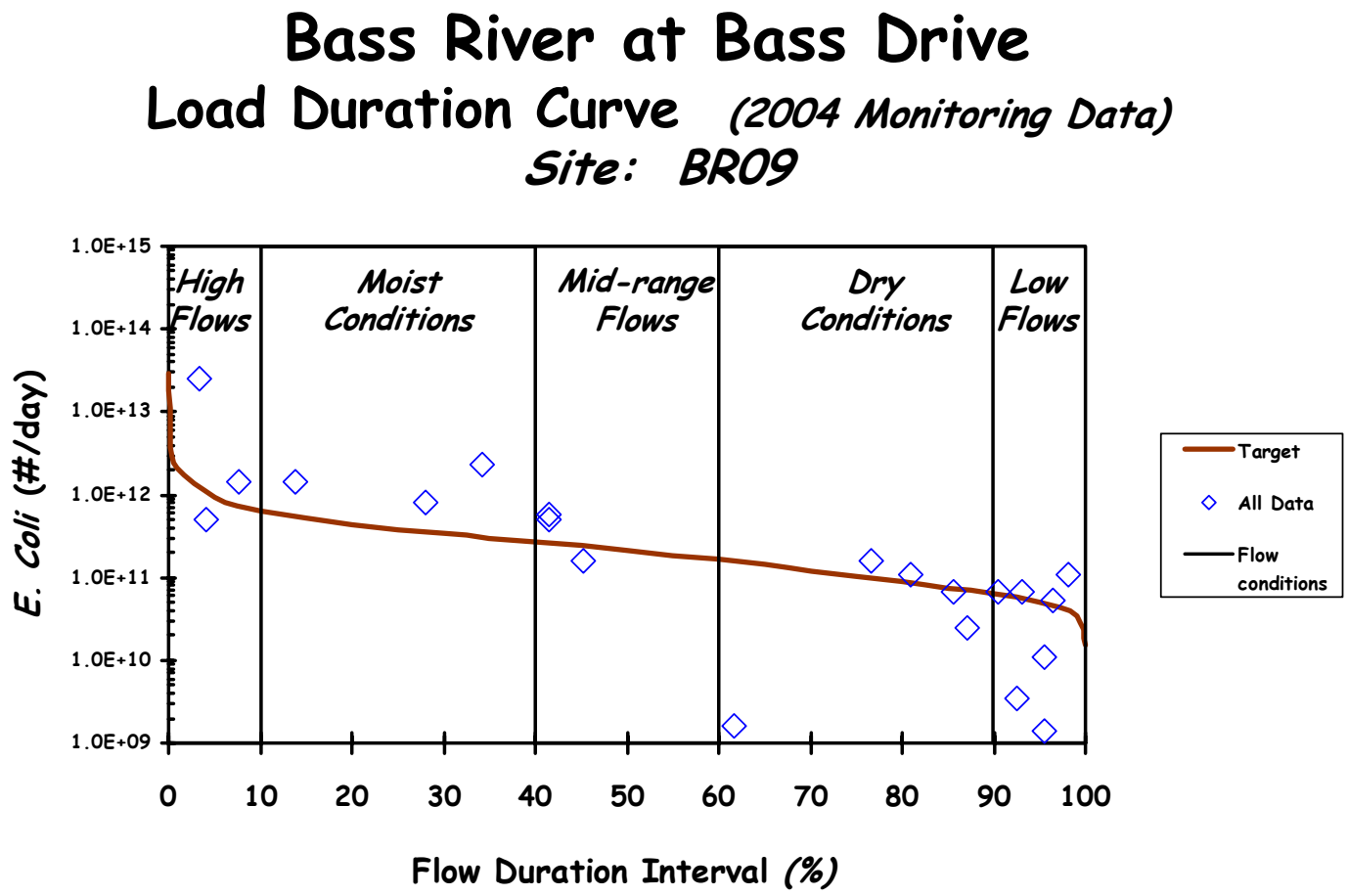

Figure A-2. Bass River at Bass Drive. Load duration curved based on daily geometric mean.
Site: BR-09

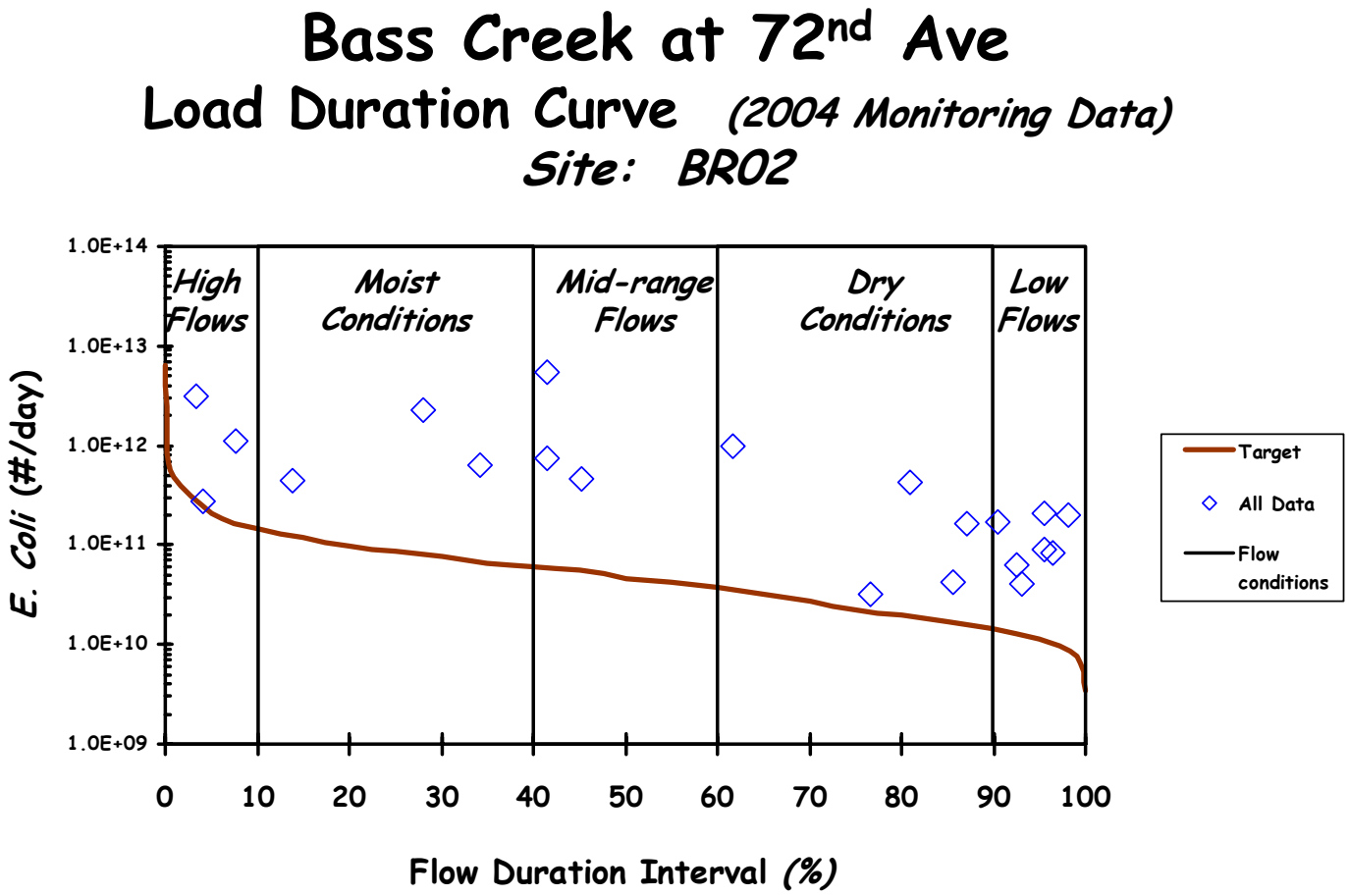

Figure A-3. Bass Creek at 72nd Avenue. Load duration curve based on daily geometric mean. Site: BR-02.

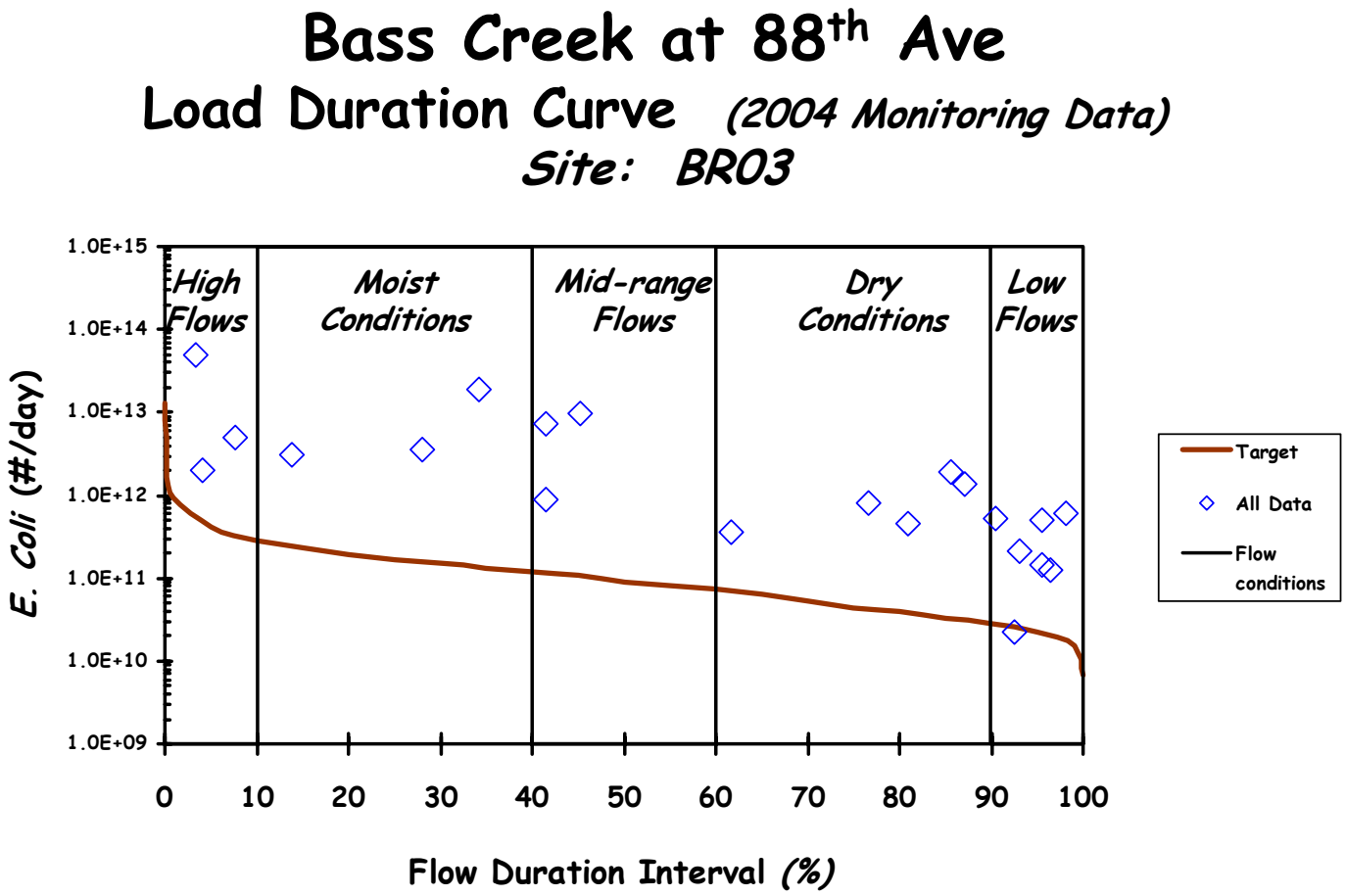

Figure A-4. Bass Creek at 88th Avenue. Load duration curve based on daily geometric mean. Site: BR-03.

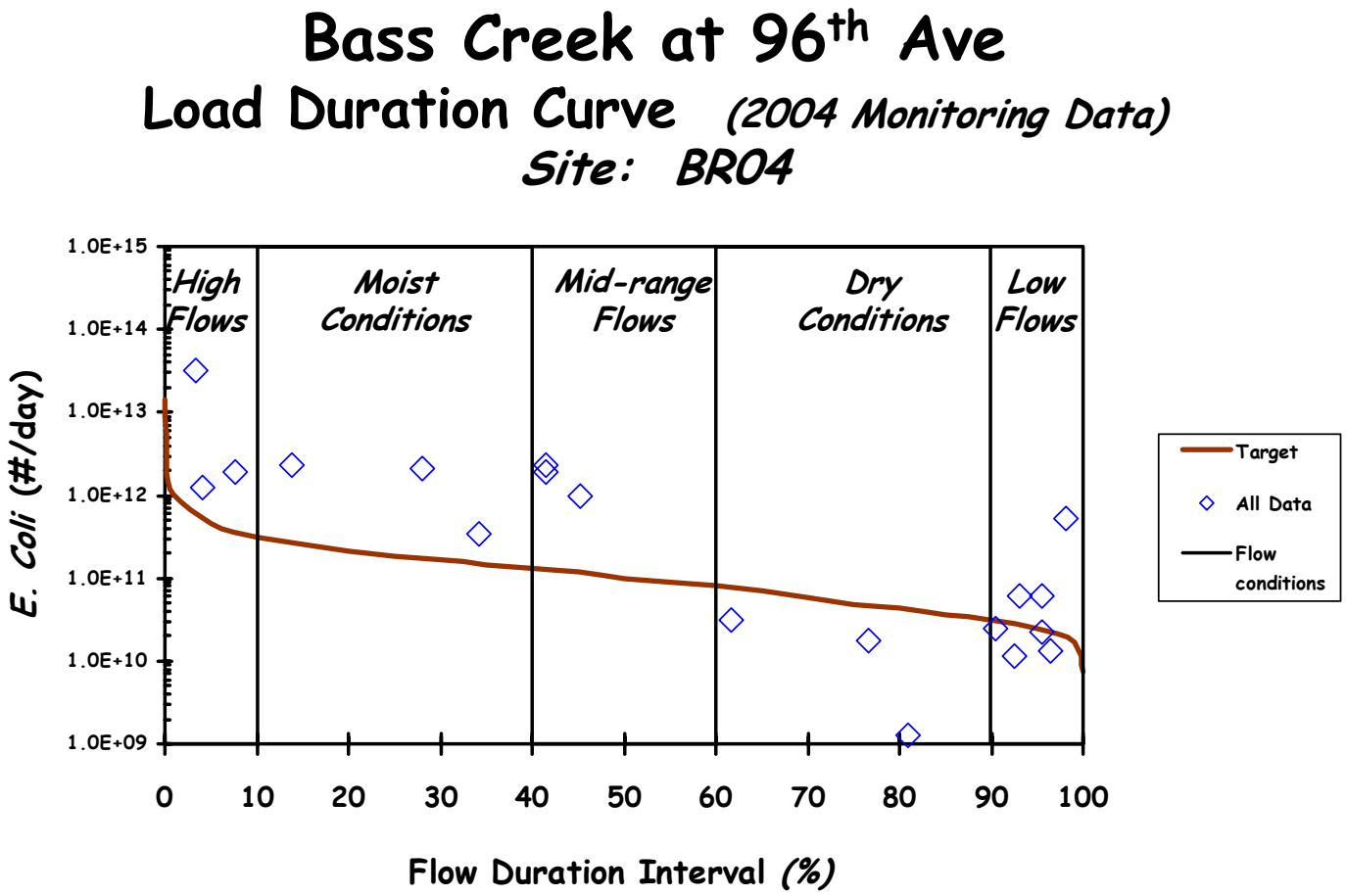

Figure A-5. Bass Creek at 96th Avenue. Load duration curve based on daily geometric mean. Site: BR-04.

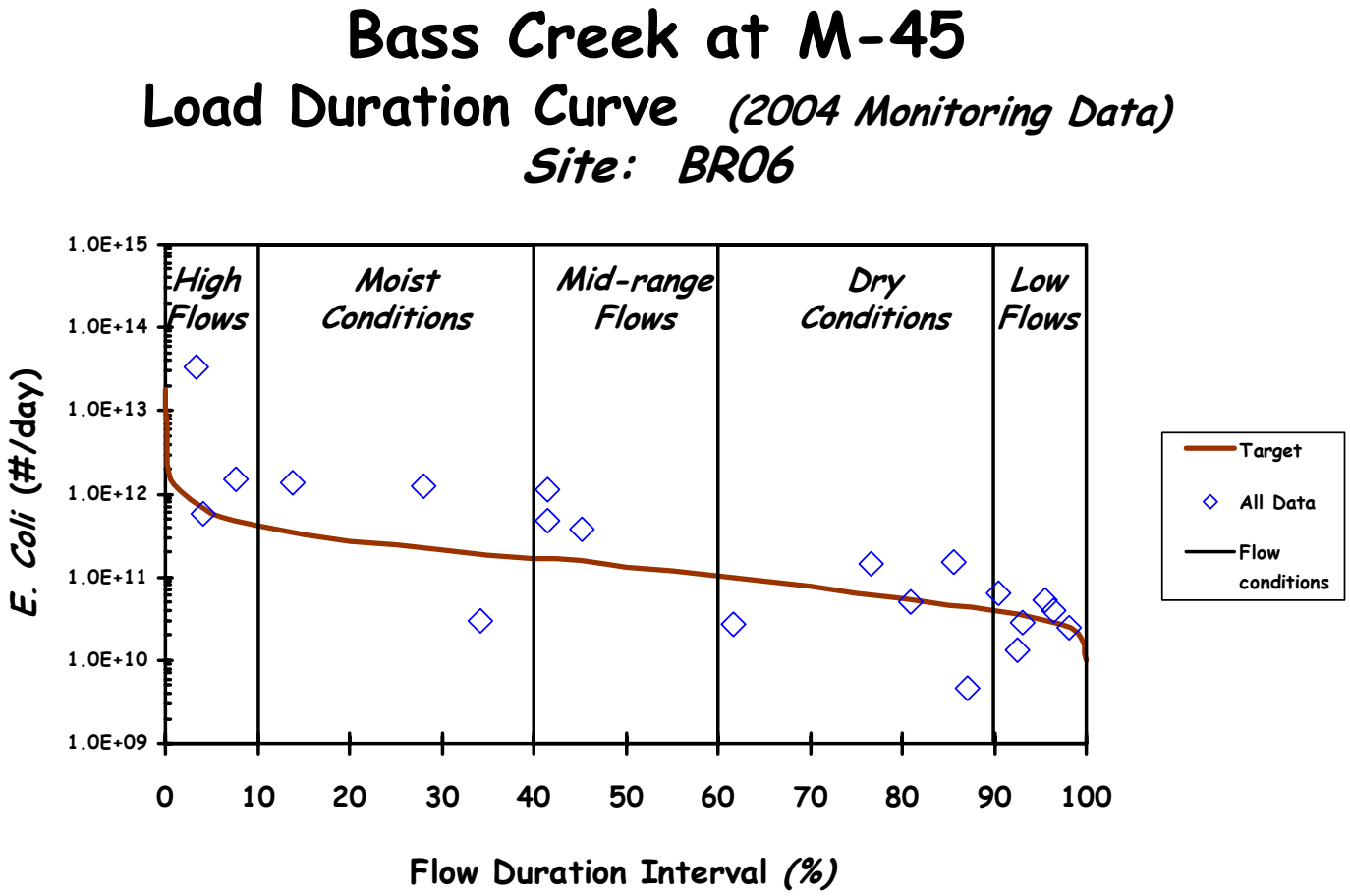

Figure A-6. Bass Creek at M-45. Load duration curve based on daily geometric mean. Site: BR-06.

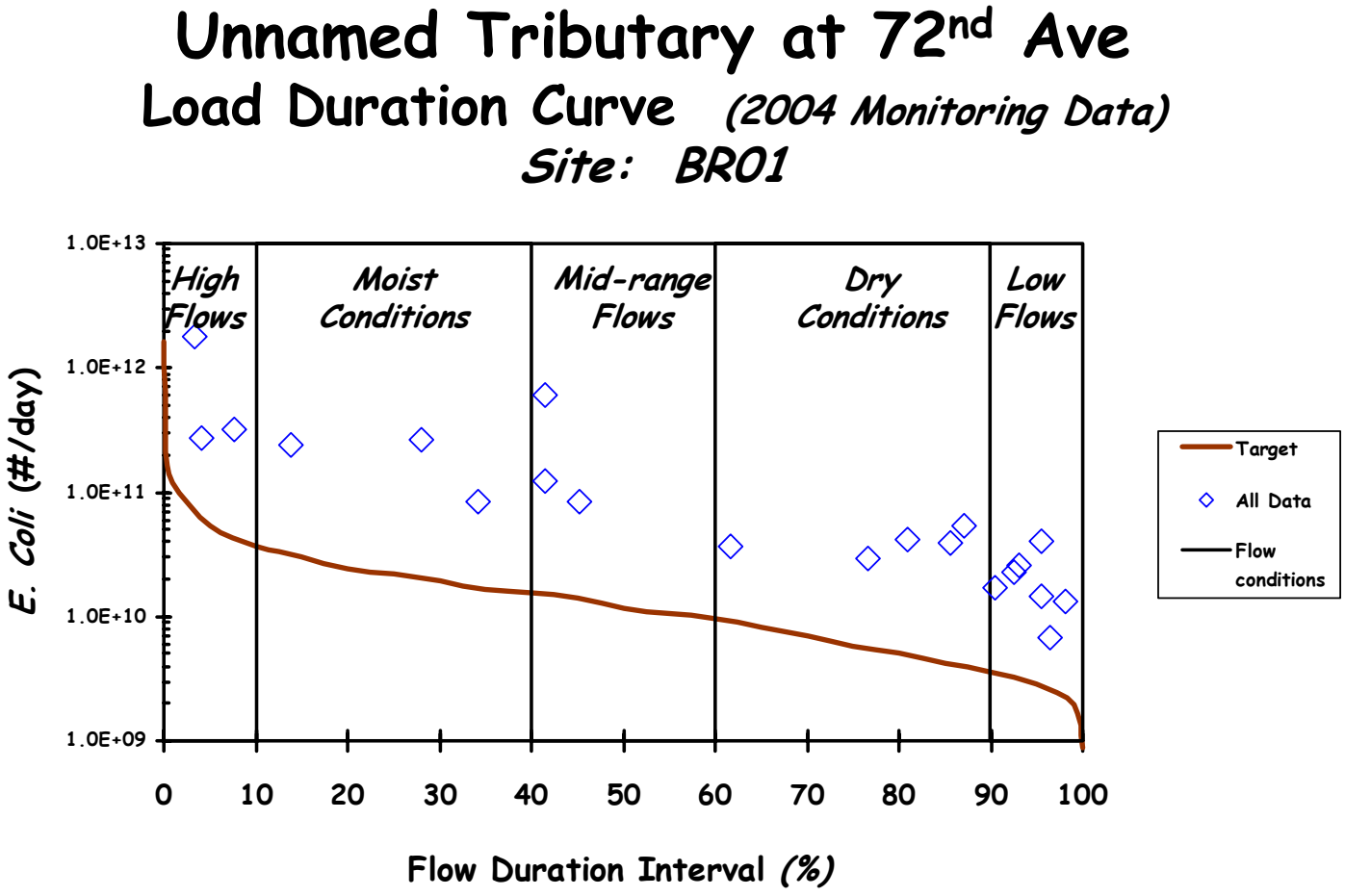

Figure A-7. Unnamed tributary at 72nd Avenue. Load duration curve based on daily geometric mean. Site: BR-01.

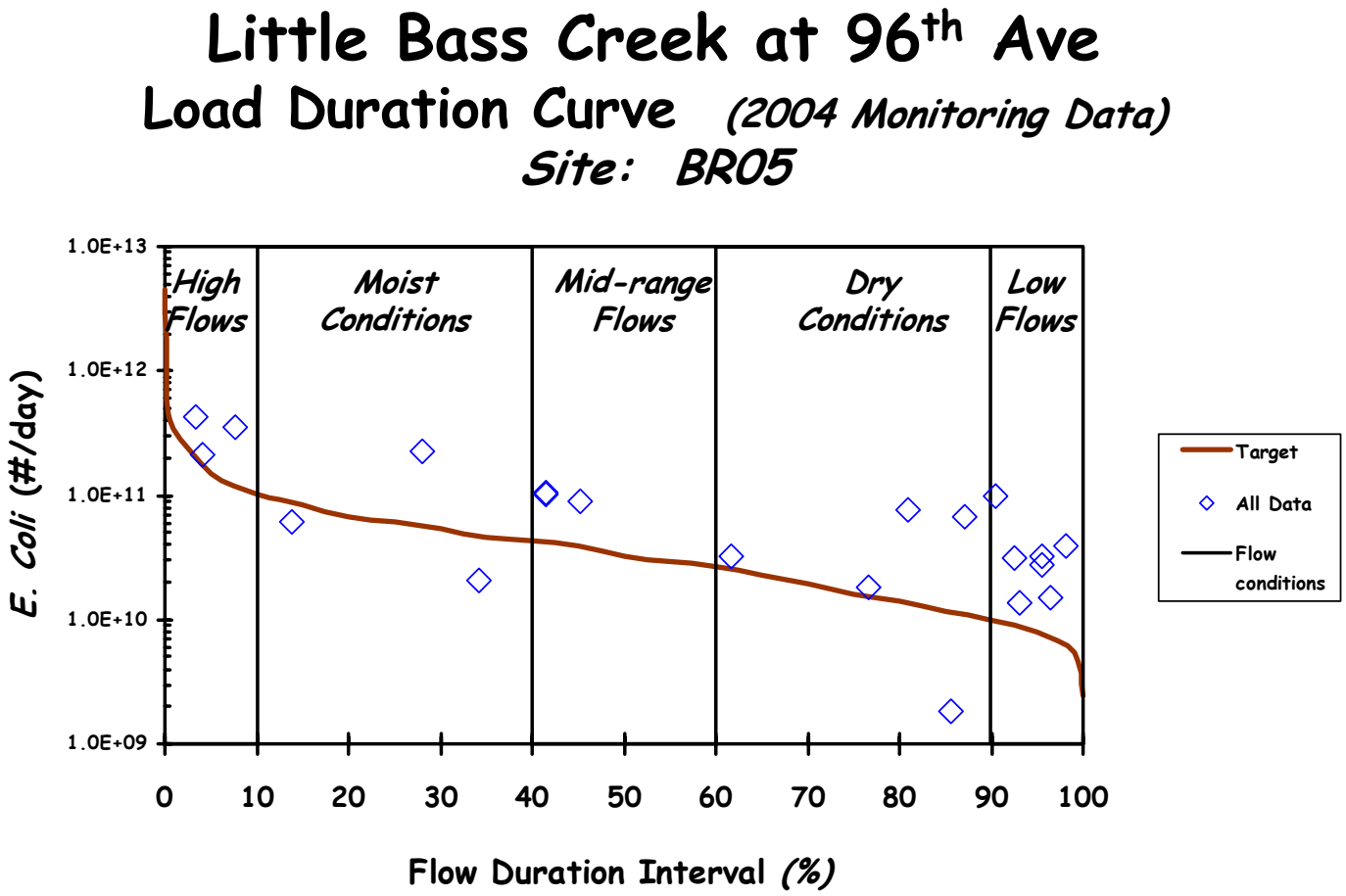

Figure A-8. Little Bass Creek at 96th Avenue. Load duration curve based on daily geometric mean. Site: BR-05.

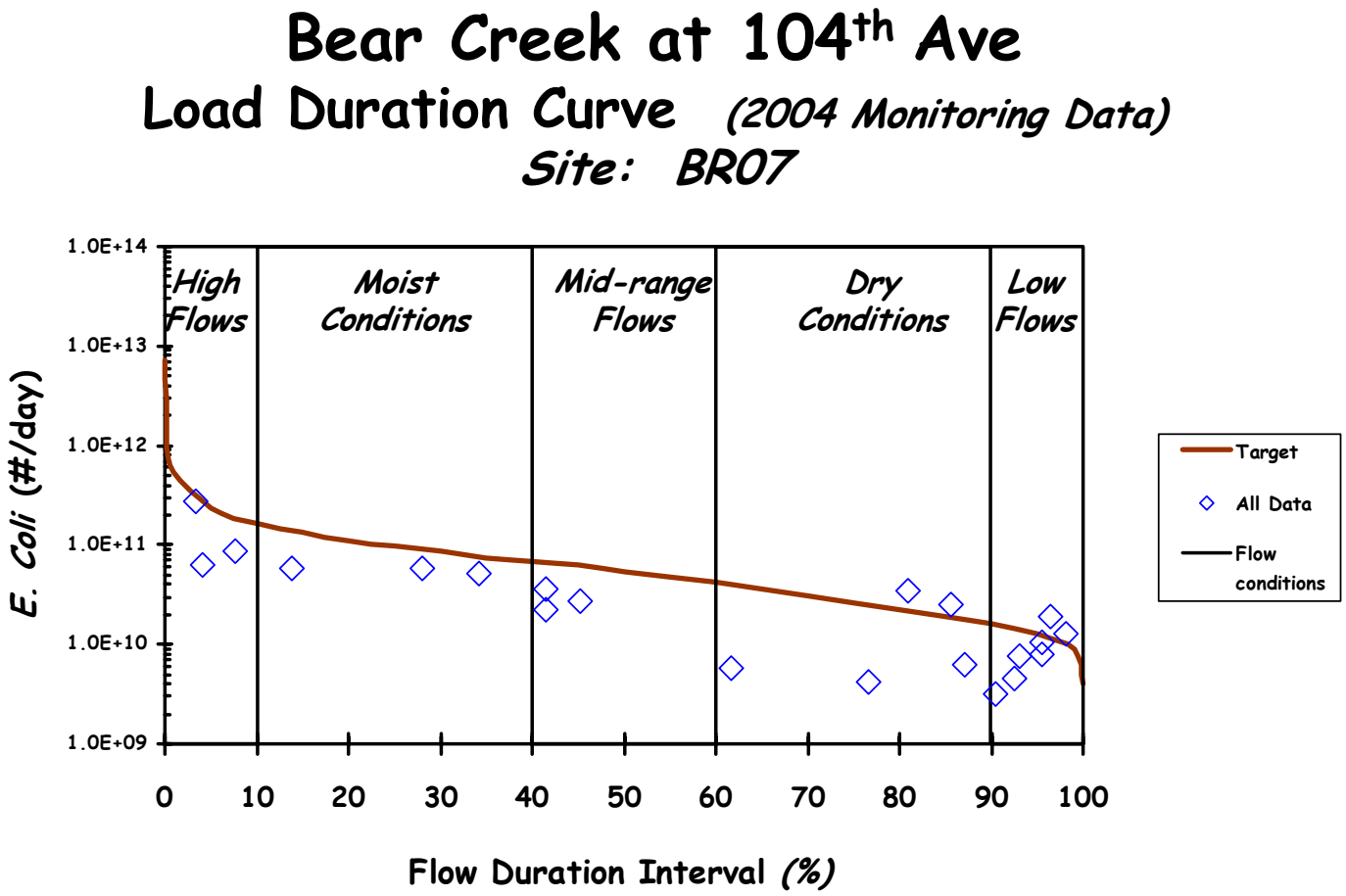

Figure A-9. Bear Creek at 104th Avenue. Load duration curve based on daily geometric mean. Site: BR-07.